

**A WHITE PAPER ON
ELECTRIC AND MAGNETIC FIELD (EMF)
POLICY AND MITIGATION OPTIONS**

PREPARED BY

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ON EMF ISSUES**

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EXECUTIVE SUMMARY

Over the last two decades concern about the health effects of electric and magnetic fields (EMF) has increased. Early scientific studies reported a weak association between increased rates of cancer and closeness to certain kinds of power lines that can cause strong electric and magnetic fields. As more electric facilities are built to meet growing demands for electricity, policy makers will increasingly be faced with questions regarding the potential health impacts of EMF. This report is the result of an interagency work group that was formed to examine these issues and provide useful, science-based information to policy makers in Minnesota.

Electric and magnetic fields are a basic force of nature generated by electricity from both natural and human sources. Exposure to EMF comes from high voltage transmission lines and distribution lines, wiring in buildings, and electric appliances. Electric fields are easily shielded by common objects such as trees, fences, and walls. Magnetic fields are difficult to shield; this is why magnetic fields produced by power lines can extend into people's homes.

Transmission and distribution lines are part of the complete electric power system. Transmission lines carry between 69 and 500 kilovolts (kV) of electricity and transport it from generation sources to regions of the state needing electricity. Primary distribution lines generally carry less than 69 kV of electricity and bring it from transmission lines to homes, offices, and other sites where there are end users of electricity.

Based on forecasts of future electrical use, Minnesota has now reached the point at which new generation and transmission capacity is needed. Over the ten years from 1990 to 2000, total annual electric consumption in the State grew by 27 percent; summer peak demand is predicted to grow by 16 percent over the next ten years. Several transmission expansion projects are planned over the next ten years to meet this demand. These projects will need to be reviewed and approved by the Public Utilities Commission and the Environmental Quality Board.

Research on the health effects of EMF has been carried out since the 1970s. Epidemiological studies have mixed results – some have shown no statistically significant association between exposure to EMF and health effects, and some have shown a weak association. More recently, laboratory studies have failed to show such an association, or to establish a biological mechanism for how magnetic fields may cause cancer. A number of scientific panels convened by national and international health agencies and the U.S. Congress have reviewed the research carried out to date. Most concluded that there is insufficient evidence to prove an association between EMF and health effects; however, many of them also concluded that there is insufficient evidence to prove that EMF exposure is safe.

In deciding whether or how much to regulate EMF, decision-makers have several possible options. Each approach has advantages and disadvantages. At one extreme, regulators can require virtual certainty of harm before they address it. At the other extreme, proposers of a project would need to demonstrate its safety before regulators would allow them to proceed. Several options along this continuum are presented below for regulators to consider when routing power lines.

Several EMF exposure mitigation options are available. Mitigation options for transmission lines include increasing distance to the EMF source, phase cancellation by changing the proximity of the conductors, shielding the EMF source, and reducing voltage or current levels on the lines. Principles for decreasing EMF from primary distribution lines are similar and include increasing the right-of-way around distribution lines, phase cancellation, and burying the lines. There are also several options for mitigating EMF exposure in the home, including increasing distance to operating appliances and properly following electrical codes for wiring the home.

The Minnesota Department of Health (MDH) concludes that the current body of evidence is insufficient to establish a cause and effect relationship between EMF and adverse health effects. However, as with many other environmental health issues, the possibility of a health risk from EMF cannot be dismissed. Construction of new generation and transmission facilities to meet increasing electrical needs in the State is likely to increase public exposure to EMF and public concern regarding potential adverse health effects.

Given the questions and controversy surrounding this issue, several Minnesota agencies that regularly deal with electric generation and transmission formed an Interagency Work Group to provide information and options to policy makers. Work Group members included representatives from the Department of Commerce, the Department of Health, the Pollution Control Agency, the Public Utilities Commission, and the Environmental Quality Board. Based on its review, the Work Group believes the most appropriate public health policy is to take a prudent avoidance approach to regulating EMF. Based on this approach, policy recommendations of the Work Group include:

- Apply low-cost EMF mitigation options in electric infrastructure construction projects;
- Encourage conservation;
- Encourage distributed generation;
- Continue to monitor EMF research;
- Encourage utilities to work with customers on household EMF issues; and
- Provide public education on EMF issues.

CHAPTER 3: ASSESSMENT OF EMF HEALTH EFFECTS RESEARCH

The Minnesota Department of Health (MDH) tracks EMF health effects research on a regular and ongoing basis to monitor for any new developments in EMF science and policy. This effort includes reviewing the latest research published in scientific journals; participating in conferences related to EMF, exposure assessment, and risk assessment; and consulting with leading EMF scientists affiliated with federal and international health agencies.

Staff of the Minnesota Department of Health conducted an evaluation of EMF health effects research. MDH's evaluation covered three areas: The historical body of published research on the topic; conclusions drawn by various scientific review committees based on review of the historical research; and more recent scientific studies published since the review committees developed their conclusions. Each of these is discussed below. MDH staff also consulted with leading EMF researchers at the National Institute of Environmental Health Sciences (NIEHS) EMF Research and Public Information Dissemination (RAPID) Program, the U.S. Environmental Protection Agency, and the National Toxicology Program to complete this evaluation. For additional information about EMF health effects research, refer to the web sites at the end of this chapter and references listed at the end of this report.

Overview of Historical EMF Health Effects Research

It is beyond the scope of this evaluation to conduct a historical review of all EMF research. Therefore, an overview is provided, primarily on the health effects of magnetic fields, to provide context for the discussion of review committee conclusions and the most recent research.

Epidemiological Studies

Research on the health effects of EMF began in the late 1960's and was originally focused on electric fields. In 1979, an epidemiological study reported a statistical association between surrogate indicators of residential magnetic field exposure (e.g., wire coding, the practice of estimating someone's exposure to magnetic fields based on the size of power line, type of line, and distance between a power line and someone's home) and two- to three-fold increases in leukemia risk among U.S. children (Wertheimer et al., 1979). A second study found similar results (Savitz et al., 1988). This early research brought the issue of magnetic field-related health risks to the attention of scientists and the public. More recent studies have used direct measurements (e.g., personal monitors, which participants wear all day to take regular measurements of the magnetic fields to which the person is exposed) to estimate magnetic field exposures. These studies show mixed results – i.e., some have reported no statistically significant association (Linnet et al., 1997; Dockerty et al., 1998; McBride et al., 1999) and others have reported a weak association (Green et al., 1999; Schuz et al., 2001).

The inconsistencies in the epidemiological research have raised questions and concerns about whether there is a true "cause and effect" relationship between magnetic fields and leukemia or any other adverse health effects. Scientists generally have agreed that the epidemiological studies, by themselves, cannot establish a cause and effect relationship, and that additional evidence (e.g., laboratory studies) is needed to determine if there is a true relationship between magnetic fields and adverse effects.

Laboratory Studies

In recent years there have been several laboratory studies in animals conducted under controlled experimental conditions (NIEHS, 1999; NTP, 1999; Takebe et al., 2001). These studies have failed to provide support for a relationship between magnetic fields and adverse human health effects, even at high exposure levels. In addition, studies of isolated cells have failed to establish an understood biological mechanism of action for how magnetic fields may cause cancer (NIEHS, 1999; Takebe et al., 2001). These factors have raised doubt in the scientific community about what relationship, if any, exists between magnetic field exposure and childhood leukemia or any other adverse health effect.

Discussion

Many researchers have determined that important elements to confirm causality are currently lacking for EMF and human disease, including strength of association, consistency and specificity of observations, appropriate temporal relationship, dose response relationship, biological plausibility, and experimental verification. Researchers also have widely acknowledged the limitations of many magnetic field epidemiological studies, including the use of surrogate indicators (e.g., wiring code configurations) to estimate magnetic field levels; the small number of cases or subjects, particularly in high exposure categories; and the potential for bias due to factors related to selection, misclassification, recall, and confounding.

While some researchers disagree about the possibility of EMF causing adverse health effects, it is known that EMF associated with electrical power is extremely low frequency (60 hertz) relative to other types of fields commonly found in our environment (e.g., AM/FM radio, television, and cellular phone frequencies). Very high frequency fields, such as gamma rays, can break molecular bonds. Human exposure to gamma rays can cause direct DNA damage. Lower frequency fields such as microwaves do not cause direct DNA damage, but can have significant heating effects. Electrical power EMFs are not capable of causing direct DNA damage and are generally considered to have no thermal effects. Researchers continue to investigate possible mechanisms for how low frequency EMF may cause indirect biological effects. However, to date, there is limited evidence to conclude that indirect biological effects cause adverse health effects.

Conclusions of Scientific Review Committees

Several EMF scientific review committees have been convened by the U.S. Congress and by federal and international health agencies (NRC, 1996; NIEHS, 1999; NRPB, 2001;

IARC, 2001) to review and evaluate the extensive historical body of scientific literature on EMF health effects and to draw conclusions. The committees included leading EMF researchers and experts in multiple disciplines in the U.S. and abroad. The most prominent of the review committees and their conclusions are described and summarized below, starting with the earliest reviews and ending with the most recent.

American Physical Society (1995)

In 1995 the American Physical Society (APS), which is a national professional organization of U.S. physical scientists, concluded the following:

Physicists are frequently asked to comment on the potential dangers of cancer from electromagnetic fields that emanate from common power lines and electrical appliances. While recognizing that the connection between power line fields and cancer is an area of continuing study by research workers in many disciplines in the United States and abroad, we believe that it is possible to make several observations based on the scientific evidence at this time. We also believe that, in the interest of making the best use of the finite resources available for environmental research and mitigation, it is important for professional organizations to comment on this issue.

The scientific literature and the reports of reviews by other panels show no consistent, significant link between cancer and power line fields. This literature includes epidemiological studies, research on biological systems, and analyses of theoretical interaction mechanisms. No plausible biophysical mechanisms for the systematic initiation or promotion of cancer by these power line fields have been identified. Furthermore, the preponderance of the epidemiological and biophysical/biological research findings have failed to substantiate those studies that have reported specific adverse health effects from exposure to such fields. While it is impossible to prove that no deleterious health effects occur from exposure to any environmental factor, it is necessary to demonstrate a consistent, significant, and causal relationship before one can conclude that such effects do occur. From this standpoint, the conjectures relating cancer to power line fields have not been scientifically substantiated.

These unsubstantiated claims, however, have generated fears of power lines in some communities, leading to expensive mitigation efforts and, in some cases, to lengthy and divisive court proceedings. The costs of mitigation and litigation relating to the power line/cancer connection have risen into the billions of dollars and threaten to go much higher. The diversion of these resources to eliminate a threat which has no persuasive scientific basis is disturbing to us. More serious environmental problems are neglected for lack of funding and public attention, and the burden of cost placed on the American public is incommensurate with risk, if any.

National Research Council (1997)

In 1991 the National Research Council convened an expert committee with experience in several scientific disciplines. The committee reviewed and evaluated the existing scientific information on the possible effects of exposure to electric and magnetic fields on the incidence of cancer, on reproduction and developmental abnormalities, and on neurobiological response, as reflected in learning and behavior. The committee summarized its conclusions in its 1997 report, "Possible Health Effects of Exposure to Residential Electric and Magnetic Fields."

Based on a comprehensive evaluation of published studies relating to the effects of power frequency electric and magnetic fields on cells, tissues, and organisms (including humans), the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard. Specifically, no conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produce cancer, adverse neurobehavioral effects, or reproductive developmental effects.

The committee reviewed residential exposure levels to electric and magnetic fields, evaluated the available epidemiologic studies, and examined laboratory investigations that used cells, isolated tissues, and animals. At exposure levels well above those normally encountered in residences, electric and magnetic fields can produce biologic effects (promotion of bone healing is an example), but these effects do not provide a consistent picture of a relationship between the biological effects of these fields and health hazards. An association between residential wiring configurations (called wire codes) and childhood leukemia persists in multiple studies, although the causative factor responsible for that statistical association has not been identified. No evidence links contemporary measurements of magnetic-field levels to childhood leukemia.

National Institute of Environmental Health Sciences (1999)

In 1992 the U.S. Congress instructed the National Institute of Environmental Health Sciences (NIEHS) to direct a program of research and analysis to evaluate the potential for health risks from EMF exposure. In 1999 the NIEHS released its report, "Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields." It is based on both review of the historical literature and results of NIEHS-sponsored studies. The NIEHS concluded:

The scientific evidence suggesting that ELF-EMF [Extremely Low Frequency Electric and Magnetic Fields] exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the

epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of small increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects (including increased cancers in animals) have been reported. No indication of increased leukemias in experimental animals has been observed.

The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. The human data are in the "right" species, are tied to "real life" exposures and show some consistency that is difficult to ignore. This assessment is tempered by the observation that given the weak magnitude of these increased risks, some other factor or common source of error could explain these findings. However, no consistent explanation other than exposure to ELF-EMF has been identified.

Epidemiological studies have serious limitation in their ability to demonstrate a cause and effect relationship whereas laboratory studies, by design, can clearly show that cause and effect are possible. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between exposure to ELF-EMF at environmental levels and changes in biological function or disease status. The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to ELF-EMF, but cannot completely discount the epidemiological findings.

The NIEHS concludes that ELF-EMF exposure cannot be recognized at this time as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of risk to currently warrant concern.

Institute of Electrical and Electronics Engineers, Committee on Man and Radiation (2000)

In 1999 the Institute of Electrical and Electronics Engineers, Engineering in Medicine and Biology Society convened the Committee on Man and Radiation (COMAR). This committee included experts on health and safety issues related to electromagnetic fields, from power line through microwave frequency ranges. The committee concluded in their technical information statement:

In recent years concerns have been raised about the biological effects of exposure to electric and magnetic fields at extremely low frequencies (ELF), particularly those associated with the distribution and utilization of electric power. In 1989, the Institute of Electrical and Electronics Engineers (IEEE) issued an "Entity Position Statement" which stated that "there is not enough relevant scientific data to establish whether common exposure to power-frequency fields should be considered a health hazard" and that "there is general agreement that more research is needed to define safe limits of human exposure to power-frequency fields." After examination of relevant research reports published during the last ten years, COMAR concludes that it is highly unlikely that health problems can be associated with average 24-hour field exposure to power frequency magnetic fields of less than 1 microT (10 mG). Good laboratory evidence shows that magnetic fields 100 to 10,000 times higher than this level, either ELF sinusoidal or pulsed, can induce a variety of biological effects, including beneficial health effects such as bone or tissue healing. Many of the reports of effects of weaker fields should be considered preliminary, as some observations have not been reproduced in different laboratories, while others, observed in cells, have not been clearly connected to effects in intact animals. Also, the means of interaction of low-level ELF fields with cells, tissues or laboratory animals is not fully understood; therefore the health impacts of such weak fields on intact animals and humans, if any, cannot be predicted or explained. Further research is needed to confirm or negate reports of effects of weak fields, and to determine mechanisms and relevance of these effects to actual health hazards. Continued study in this complicated area will enhance our understanding of biological systems, as well as help identify levels and types of ELF exposure that may be deleterious to human health.

National Radiological Protection Board (Advisory Group on Non-Ionizing Radiation) (2001)

In March 2001, the British National Radiological Protection Board, Advisory Group on Non-Ionizing Radiation, conducted an extensive review of the EMF research. The Advisory Group concluded:

Laboratory experiments have provided no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggest that they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukaemia in children. In practice, such levels of exposure are seldom encountered by the general public in the UK [United Kingdom]. In the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the epidemiological evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children. Unless, however, further research indicates that the finding is due to chance or some currently unrecognized artifact, the possibility remains that intense and

prolonged exposures to magnetic fields can increase the risk of leukemia in children.

International Agency for Research on Cancer (2001)

In June 2001, the International Agency for Research on Cancer (IARC) convened a meeting of 21 scientific experts from 10 countries to evaluate possible carcinogenic hazards to humans from exposures to EMF. They concluded:

Since the first report suggesting an association between residential electric and magnetic fields and childhood cancer, notably leukemia, was published in 1979, dozens of studies have examined this association. Overall, for the vast majority of children who are exposed to residential ELF [extremely low frequency] magnetic fields less than 0.4 microtesla [4 milligauss], there is little evidence of any increased risk for leukemia. There is no evidence that electric fields are associated with childhood leukemia, and there is no consistent relationship between childhood brain tumors and residential ELF electric and magnetic fields. However, pooled analyses of data from a number of well conducted studies show a fairly consistent statistical association between childhood leukemia and power-frequency residential magnetic field strengths above 0.4 microtesla, with an approximately two-fold increase in risk. This is unlikely to be due to chance, but may be affected by selection bias. Therefore, this association between childhood leukemia and high residential magnetic field strengths was judged *limited evidence* for excess cancer risk in exposed humans. [Emphasis in original.]

There is no consistent evidence that residential or occupational exposures of adults are related to excess risks of cancer at any site [in the body], although in one Swedish study combined residential and occupational exposures were associated with a significantly increased risk for leukemia subtypes except chronic lymphocytic leukemia. Evidence for excess cancer risks of all other kinds, in children and in adults, as a result of exposure to ELF electric and magnetic fields was considered *inadequate*. [Emphasis in original.]

Numerous studies to investigate carcinogenicity of magnetic fields have been conducted in experimental animals. These have included long-term bioassays of exposures to magnetic fields alone, and exposures of rats and mice to magnetic fields in combination with known carcinogens. Bioassays of magnetic fields alone generally were negative, although one study that was conducted in both mice and rats of both sexes showed non-exposure related increases in thyroid C-cell tumors in male rats only. Multistage carcinogenesis studies showed no consistent enhancement of chemically initiated mammary tumors in rats or of skin tumors in mice. Magnetic fields had no effects on the incidence of chemically initiated liver tumors in rats or of leukemia/lymphoma in mice or rats. Overall, evidence of carcinogenicity of ELF magnetic fields in experimental animals was judged inadequate. No data on carcinogenicity to animals of static magnetic fields, or of static or ELF electric fields, were available to the working group.

Although many hypotheses have been put forward to explain possible carcinogenic effects of ELF electric or magnetic fields, no scientific explanation for carcinogenicity of these fields has been established.

Overall, extremely low frequency magnetic fields were evaluated as possibly carcinogenic to humans (Group 2B), based on the statistical association of higher level residential ELF magnetic fields and increased risks for childhood leukemia. Static magnetic fields and static and extremely low frequency electric fields could not be classified as to carcinogenicity to humans (Group 3).

Note that the term "possibly carcinogenic to humans" is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals. This classification is the weakest of three categories used by IARC to classify potential carcinogens.

Japan EMF Research Program (2001)

In the 1990's Japan conducted an EMF research program comparable in scope and magnitude to the NIEHS EMF RAPID program. The focus of this program was laboratory testing for possible cancer effects such as changes in gene expression or increased risks for tumors. In 2001 the results of this research program were published in the book, *Biological and Health Effects from Exposure to Power-Line Frequency Electromagnetic Fields: Confirmation of Absence of Any Effects at Environmental Field Strengths* (Takebe et al., 2001). The researchers concluded:

By the middle of 1999, as mentioned in the EMF RAPID report, there was little evidence for any adverse health effects from EMF exposure. About half of the epidemiological studies have suggested possible health effects, but almost all of the experimental studies with animals have been negative. Thus it appears there is little possibility of finding new adverse health effects from EMF in the future. Very high intensity EMF can have certain biological effects, but they occur only with EMF more than 10,000 times higher than those found in real-world environments. Furthermore, even with the biological indicator which gave the positive results with 400 mT [4,000,000 milligauss] for 1 hour, elongated exposure with 5 mT [50,000 milligauss] for 6 weeks did not yield any effect. We conclude that adverse human health effects as a result of environmental power-frequency EMF either do not occur or that they are undetectable because they occur so rarely they cannot be separated by other processes.

Health Council of the Netherlands (2001)

In May 2001 the Health Council of the Netherlands, Electromagnetic Fields Committee, completed an annual review of the research on possible health effects of exposure to electromagnetic fields (HCN, 2001). This review included several recently published EMF studies, including two meta-analyses (Ahlbom et al., 2000 and Greenland et al., 2000).

The committee concludes that these recent meta-analyses show a consistent association between relatively high measured or calculated magnetic field strengths and an increased risk of childhood leukemia. However, from an epidemiological point of view, an association with a relative risk of smaller than 2 is to be considered weak. Furthermore, the committee does not think that either 0.3 uT [3 mG] or 0.4 uT [4 mG] should be regarded as a definite threshold field strength, above which the risk is suddenly increased. This view is based upon the belief that it is not appropriate to consider measured and calculated fields strengths in the same light. Where researchers have obtained field strength data by measurement, the contributions made by all sources inside and outside the home are taken into account, with the result that the study data is reasonably consistent with overall exposure. Where calculated data is used, however, only the strength of the field generated by a single external source (typically a high voltage power line) is considered. In studies using calculated field strength data actual exposure is therefore underestimated. Furthermore, it is apparent from research carried out in the UK and elsewhere that in a large proportion of homes where relatively high field strengths occur, the fields are not primarily attributable to external sources such as high-voltage power lines (Day 99).

The committee would emphasise that there is no known mechanism that could account for the association referred to above. Because the association is only weak and with out a reasonable biological explanation, it is not unlikely that it could also be explained by chance or by an artefact. The committee therefore sees no reason to modify its earlier conclusion that the association is not likely to be indicative of a causal relationship.

It therefore remains the committee's belief that it is not likely that children (or adults) living near to high-voltage power lines are at risk through exposure to electromagnetic fields generated by those lines. This view is consistent with that of the Advisory Group on Non-ionising Radiation – a committee of the UK's National Radiological Protection Board, chaired by Sir Richard Doll – as published in early March 2001.

MDH Review of Recent Scientific Literature

As part of its ongoing evaluation of EMF research, MDH completed a literature review of research published since the 1999 NIEHS scientific review committee report. This review included over 50 studies published in scientific journals and/or presented at the June 2001 International Bioelectromagnetics Society Meeting. It is beyond the scope of this assessment for MDH to comment on all reviewed EMF studies. The comments below focus on selected recent EMF studies that are most prominent. It is important to recognize that these studies are a small fraction of the total EMF research published to

date and of EMF research reviewed by the scientific committees convened by federal and international health agencies to date.

Canadian Studies

Two Canadian studies published in 1999 demonstrate the inconsistencies observed in the EMF epidemiological research (Green et al., 1999; McBride et al., 1999). Green et al., evaluated childhood leukemia and EMF exposure in Ontario, Canada. This study showed a weak association between contemporary measured fields outside residences and childhood leukemia. This study also found a positive association when comparing fields measured with personal monitors and childhood leukemia. However, there was no association with childhood leukemia for contemporary fields inside residences. In addition, when using wire codes (as with Wertheimer and Leeper, and Savitz) there was no association with cancer. At the same time in 1999, McBride conducted a much larger study in Ontario. This study found no association with childhood leukemia for personal monitors, contemporary measured fields inside residences, historic magnetic fields or wire codes.

National Toxicology Program Studies

In 1999 the National Toxicology Program conducted a two-year whole body exposure animal study to investigate possible effects from 50-60 hertz magnetic fields (NTP, 1999). The highest field intensity (10,000 milligauss) was considered approximately 5,000 fold greater than what was considered high intensity for homes in epidemiological studies in humans. Results showed no effects on survival and body weights and no increased incidences of neoplasms at sites for which epidemiological studies have suggested an association with magnetic fields.

British Journal of Cancer

In September 2000 researchers published a pooled analysis of EMF studies in the British Journal of Cancer (Ahlbom et al., 2000). The analysis included data from nine studies that had been conducted in Europe, Canada, New Zealand, and the U.S., including data from the 1999 McBride et al. study. Pooling data in this fashion provides a greater number of subjects and yields greater statistical power when conducting analyses.

The study reported a weak association between exposure to power frequency magnetic fields greater than 4 milligauss and childhood leukemia. Specifically, the study found that children with residential exposures to magnetic fields greater than 4 milligauss had a statistically significant relative risk estimate of two for childhood leukemia. The authors attempted to adjust for several possible confounding factors, including socioeconomic status, type of dwelling, urban or rural setting, and several others. Adjustment for these factors made little difference in the relative risk values. If there are confounding factors that would influence the result, they have yet to be identified. The authors pointed out that selection bias probably accounted for some of the elevated risk estimates, and concluded that future research should address selection bias, confounding factors, and the fact that their results were based on a very small number (0.8 percent) of leukemia cases in the high exposure groups. A second analysis of some of the same pooled studies reported similar results and limitations in a separate publication (Greenland et al., 2000).

biological mechanism to determine causality, particularly in light of the limitations of EMF epidemiological research.

MDH also has concluded that there are several important distinctions between California's evaluation process and the processes used by other scientific EMF review panels. The California evaluation was conducted by three reviewers, all from the same agency, and all with primary expertise in epidemiology. Other recent scientific EMF panels (listed above) have taken advantage of a broader review panel selected from leading U.S. and international health agencies and research organizations, representing expertise in a wide variety of disciplines (e.g., epidemiology, cellular biology, physics, statistics).

At this time it is not clear how California decision-makers will use the CDHS EMF Risk Evaluation report. A revised report is expected to be completed in 2002. MDH will continue to track EMF developments in California, as well as other states. (For more information about EMF activities in California and other states, see the Appendix).

Future Research

EMF research is continuing in the U.S. and abroad, as new methods for studies are developed to improve exposure assessment, to control for confounding and other types of bias, and to investigate possible biological mechanisms. NIEHS supports some limited extramural EMF research; however, their 5-year EMF RAPID Program has concluded, and there do not appear to be any plans to expand EMF (60 hertz) federal research at this time (NIEHS, 2001). Japan has also concluded their EMF research program; however there are some isolated studies that are ongoing.

In 2003 the World Health Organization (WHO) International EMF Project is expected to complete an assessment of non-cancer EMF health risks (WHO, 2001). This project is working in collaboration with international agencies and organizations to pool resources and knowledge about EMF; to identify gaps in knowledge; recommend focused research programs; conduct updated critical reviews of the scientific literature; and develop materials for risk communication. Note that WHO defines EMF broadly to include static, extremely low, intermediate, and radio frequency fields (up to 300 gigahertz). (For more information about the World Health EMF Research Project, see the web site: <http://www.who.int/peh-emf>).

MDH will continue to monitor important EMF health effects research. Future research efforts should focus on identifying possible biological mechanisms and identifying what aspect of a field may be hazardous. Without this information, scientists will be unable to provide policy guidance about what aspect of a field (e.g., frequency, intensity, polarization, harmonization), if any, would be appropriate to mitigate.

For More Information

For more information about EMF health risks, refer to the web sites listed below:

Minnesota Department of Health, Environmental Health Division
<http://www.health.state.mn.us/divs/eh/radiation/emf/index.html>

National Institute of Environmental Health Sciences, EMF RAPID Program
<http://www.niehs.nih.gov/emfrapid/home.htm>

World Health Organization, International EMF Research Project
<http://www.who.int/peh-emf/>

Medical College of Wisconsin, Electromagnetic Fields and Human Health
<http://www.mcw.edu/gcrc/cop/powerlines-cancer-FAQ/toc.html>

Bioelectromagnetics Journal, EMF Research Abstracts (see link at bottom of web page for BEMS 23rd annual meeting, St Paul, Minnesota)
<http://www.bioelectromagnetics.org/pubs.html>

Wisconsin Public Service Commission, EMF Background (adobe acrobat)
<http://psc.wi.gov/consumer/electric/document/brochure/6002b.pdf>

Health Council of the Netherlands
<http://www.gr.nl/engels/welcome/index.htm>

California Department of Health Services, EMF Program
<http://www.dhs.ca.gov/ps/deodc/ehib/emf/>

Virginia Department of Health, Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines, 2000 (Final Report)
<http://www.vdh.state.va.us/hhcontrol/highfinal.pdf>